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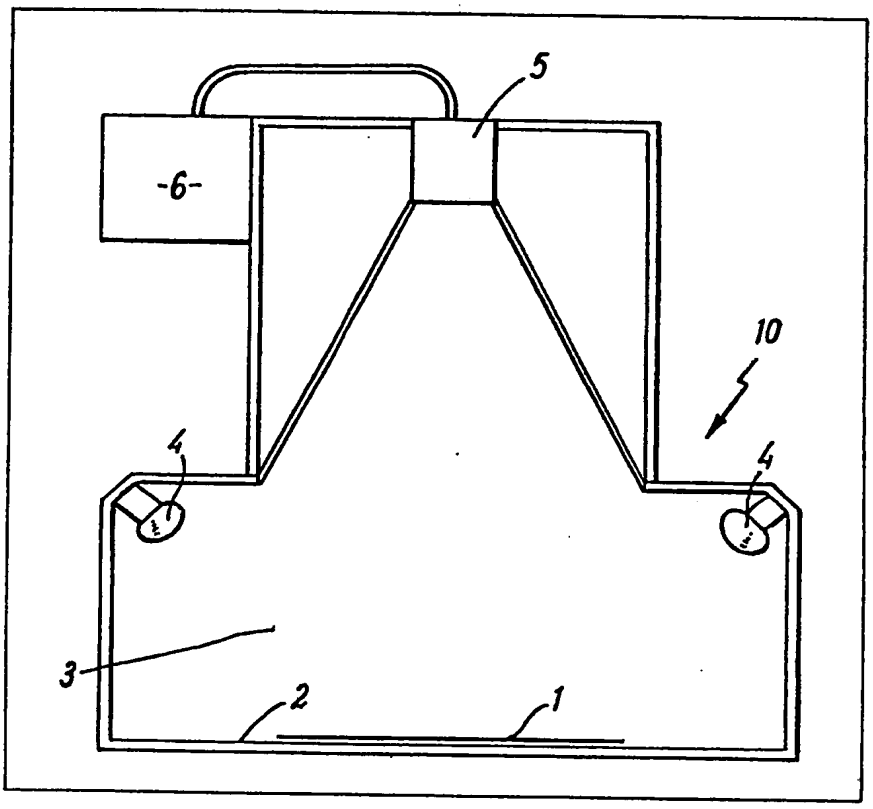
(54) Apparatus for authenticating bank notes

(57) Bank notes can be checked for authenticity using apparatus which examines properties of the note which are the same in different spatial orientations.

In particular, the entire surface area of at least one side of a bank note (1) can be subjected to spectral analysis, using light radiation reflected from or transmitted through the note. The received radiation can be integrated over the entire surface area and then compared, using a microprocessor-based system (6), with stored spectral models corresponding to different kinds of bank notes. An algorithm may be used which is capable of allowing for deviations due, for example, to soiling of a bank note.



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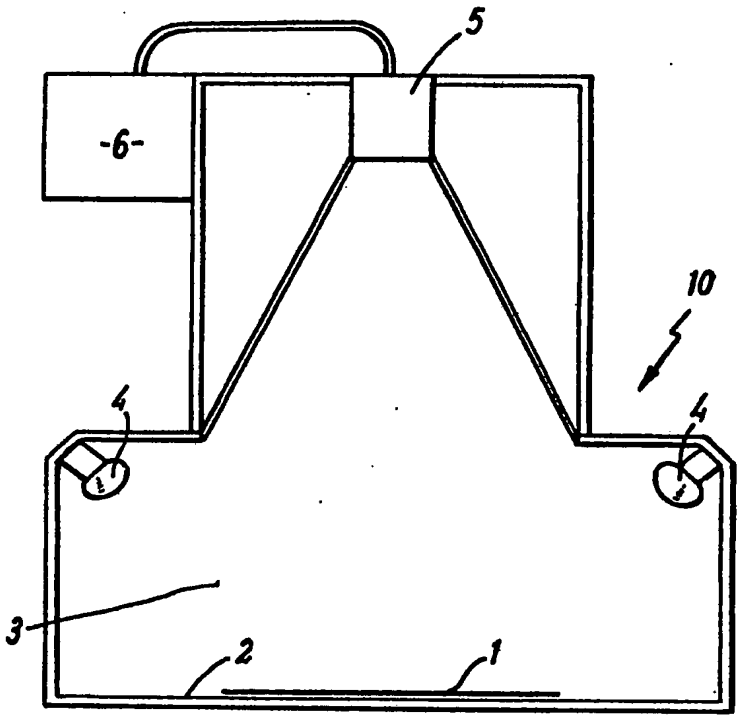
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SPECIFICATION

Apparatus for authenticating bank notes

The present invention relates to an apparatus for verification of the authenticity of bank notes.

The trend towards less labour-intensive methods of distribution of merchandise using automatic vending machines for products such as gasoline, cigarettes, food, has led to an increased interest in the automatic authentication of bank notes. The advent of inexpensive microprocessors now also makes it possible to implement sophisticated discrimination criteria, and provides a potential to design vending machines which will accept bank notes of different denominations and even different currencies. The increased use of vending machines, especially at higher denominations, of course also increases the risk of large scale fraud, and thus emphasizes the need for adequate bank note authenticity criteria.

Different bank note authentication methods are described in Patent literature, some of which are used in vending machines now commercially available. Authentication methods and verification algorithms are known from, e.g. U.S. Patent Specification 2,950,799, German Patent Specification 1774344 and Swedish Patent Specification 7606828—7. For illustration, the main known authentication methods can be grouped in three classes: thickness measuring, pattern recognising and color sensing methods.

In the first class of authentication methods, sensors are employed to measure the thickness distribution at specified portions of the bank note, corresponding to various details on the bank note where characteristic variations in thickness are produced by the printing process, watermarks or the like. The authenticity criteria are then based on comparisons with specified standard values. The thickness is measured by mechanical or optical sensors. Mechanical sensors for thickness measurements are known from e.g. British Patent Specifications 960,391, 963,586, German Patent Specifications 1,474,903, 2,423,094, Austrian Patent Specification 329,903, Swedish Patent Specifications 337,952, 357,636, 349,679, 7607927—6. Optical methods for authenticity verification using thickness variations are known from e.g. German Patent Specifications 2005016, 2365845. Combined mechanical and optical sensors are described in e.g. Swedish Patent Specification 361,372.

The second class of authentication methods is exemplified by U.S. Patent Specification 2,646,717. Swedish Patent Specification 196,238, where the pattern on a selected portion of the bank note is compared with a standard pattern by observing the modulation occurring when these patterns are superimposed and moved relative to one another.

In the third class of authentication methods, the bank note is illuminated, and the reflection and/or transmission properties of selected portions of the bank note are examined using corresponding sets of detectors, one for each portion, respectively with different spectral response characteristics (e.g. U.S. Patent Specification 3,491,243). Alternatively, selected portions of the bank note are illuminated by a plurality of light sources, one for each portion, respectively with different spectral distributions, and the transmission and/or reflection properties are evaluated and compared with standard values as a basis for the authenticity test (e.g. U.S. Patent Specifications 3,450,785, 3,679,314).

The following observations are made in relation to the three main classes of authentication methods described above.

In so far as it is intimately related to the printing process, the thickness criterion has the advantage that it can be more difficult to circumvent by fraudulent means than the criteria based on patterns or colours. On the other hand, folds or other imperfections naturally introduced by the normal use of bank notes tend to give high rejection rates for genuine, but used, bank notes — particularly if optical measurements of thickness are relied upon. The known mechanical sensors tend to be rather expensive and to require considerable maintenance to ensure correct functioning.

Of the three classes discussed, the method based on pattern recognition is probably the least satisfactory since it can be easy, by commonly available reproduction techniques, to produce copy patterns which can be distinguished from original patterns only by microscopic examination, and extremely intricate designs have to be relied upon in an attempt to achieve adequate authentication criteria.

Colour tests of the third class probably represent the best compromise between simplicity of design and satisfactory discrimination against fraud. With known designs of this class, however, the full potential of the spectral information has not been exploited in so far as sensors with relatively broad spectral sensitivity have been used.

With known apparatus in all the classes described above, only specified selected portions of the bank notes are used in the discrimination criteria. This means that a bank note has to be relatively accurately positioned in the apparatus, and the discrimination precision depends on the accuracy of such positioning. Bank note printing processes are also far from exact, and considerable variations of the location of print with respect to the edges of a bank note are common. Moreover, if the full logical advantages of microprocessors were to be exploited in the context of such known apparatus to construct vending machines which accept several denominations and even different currencies, then compromises might have to be made with respect to the selection of the fields on the bank notes to which the criteria are to be applied, and this would further adversely affect the discrimination precision.

An object of the present invention is to provide apparatus with which bank notes can be

authenticated easily and conveniently yet with satisfactory precision and without an unduly high rejection rate for genuine notes.

According to the invention therefore there is provided apparatus for authenticating a bank note comprising an analyser operable to examine said note and to produce an output representative of properties thereof; and a comparator operable to produce an output indicative of whether or not said note is authenticated based on a comparison of said analyser output with parameters representative of predetermined said properties; characterised in that said analyser is operable to produce the same or substantially the same said output for different orientations and positioning of the same said bank note.

With this measurement, due to the use of a mode of analysis which is independent, at least to a certain degree, of the spatial orientation of the bank note, it is possible to achieve satisfactory authentication precision in a simple and convenient manner and without an unduly high rate of rejection of genuine notes.

Most preferably the said analyser is operable to examine a major part of the surface of the bank note, preferably all or substantially all of such surface, on at least one side thereof, and with a view to eliminating the effect of the spatial structure of the bank note the examined properties are preferably integrated over the entire surface area of the bank note subjected to examination. Any loss of information due to said integration is an asset rather than a disadvantage in that it can eliminate the effect of the usual extremely detail-rich spatial structure which is difficult to process adequately. Instead the analyser output can have a more easily processible information content. With the invention the bank note need not be positioned in the apparatus in an exactly predetermined manner: it may even be possible to insert the note upside down or in any orientation without impeding the accuracy of the authenticity test. Moreover, it may also be possible to test different types of bank notes (different denominations, currencies) with the same optical accuracy.

Most preferably the analyser is a spectral analyser operable to analyse the spectral distribution of radiation reflected by or transmitted through the bank note from a multi-wavelength radiation source. As appropriate the analyser may utilise a sensing arrangement responsive to selected wavelengths either in the form of a continuous interference filter or a set of discrete monochromatic filters in conjunction with a sensor or sensors operable to produce electrical signals at such wavelengths.

The present invention will now be described in more detail with reference to the accompanying drawing which is a diagrammatic representation of one form of apparatus according to the invention.

The apparatus is for use in the authentication of a conventional bank note printed with a detailed colour pattern usually in one or more colours and/or shades.

The apparatus can be incorporated in an automatic merchandise vending machine or used in any suitable context as appropriate. The apparatus comprises a chamber 10 to which a bank note 1 to be authenticated is fed using appropriate feed equipment.

As shown in the drawing, the bank note 1 is introduced into an evaluation area 2 of the chamber 10, where it is placed against a black background 3, and illuminated by light sources 4 (such as filament lamps) with even spectral distributions. The light reflected from the entire upper surface of the bank note is received by an optical sensor 5. The optical sensor 5 has a sufficiently wide optical lobe and is placed at a sufficient distance from the bank note 1 to integrate the contributions from the entire surface of the bank note essentially without giving geometrical preference to any portion of the bank note. The optical sensor 5 converts the received light into spectral information of high resolution, and this information is fed in the form of electrical signals to a microprocessor-based control system 6.

Several alternative embodiments of the optical sensor 5 are conceivable. In principle, a prism or diffraction grating can be used. For economical and practical reasons, interference filters are more advantageous, either in the form of a continuous interference filter in which the band pass wavelength varies along the filter, or in the form of a set of discrete monochromatic filters. The electrical signals representative of spectral information are obtained either by moving the filter/set of filters in front of a single detector, or by having a number of detectors behind the filter/set of filters. Depending on required wavelength sensitivity, the detectors can be silicon, germanium or lead sulphide detectors.

Even more advantageous from the economical point of view is to employ light-emitting diodes (leds) as spectral sensors. Leds detect radiation in the same manner as ordinary photodiodes, but within only a narrow spectral range, approximately the same as that within which they emit light.

Instead of a light source with even spectral distribution and monochromatic detectors as described above, it is possible to employ a converse arrangement of monochromatic light sources and a detector or detectors with even spectral sensitivity. The light sources may be activated alternately one after the other in rapid succession. With this arrangement the bank note is preferably illuminated by a set of Leds in such a way that only Leds of one spectral type are lit up at a time. By storing information derived from the detector in correspondence with the actuating times as the Leds, it is possible to obtain the necessary spectral information.

By a locked switch, the authentication apparatus can be made to work selectively in either of two modes: programming mode and evaluation mode. In the programming mode, the microprocessor regards any new bank not inserted

into the evaluation area of the apparatus as a reference, and stores the corresponding spectral information in memory. In this way a set of reference spectra for different bank notes can be derived and permanently stored. When the locked switch is set to the evaluation mode, the spectrum of any new bank note inserted into the evaluation area of the apparatus is compared against the set of reference spectra in the memory. This comparison is made by a comparison algorithm, in which spectral values for the test note at different wavelengths is compared to corresponding values for each of the reference spectra. In order to allow for possible soiling etc., the algorithm may contain a free normalization parameter. Since soiling and other deficiencies arising during use of bank notes, normally introduce only a change in the overall reflectivity etc., the mean deviation obtained for genuine notes in this way is generally low, and this authentication technique provides sharp discrimination between genuine and false bank notes.

Appropriate feed devices may be provided for transferring an authenticated bank note from the chamber 10 to a storage location whilst at the same time actuating a vending machine merchandise delivery mechanism, and for transferring a non-authenticated note to a return outlet or the like.

As already mentioned, different denominations and/or currencies can be evaluated with the same optimal accuracy with the integral authenticity criterion used with the above apparatus. This implies that the full logical potential of a built-in microprocessor can be used to enable bank notes to be checked in comparison to a very large number of reference spectra for example corresponding to different denominations and currencies, for both front and back sides, for different metamers etc. In particular it is important to have adequate memory space to enable bank notes to be checked for different metamers, i.e. colour pigments which look the same to the eye but have different spectral compositions. Even though most metamer differences arise as a result of fraud, the colour pigments of genuine bank notes are occasionally changed, and the programming mode in the apparatus described above can provide for this to be taken into account.

The invention is not intended to be restricted to the details of the above embodiment which are described by way of example only. Thus, for example, it is possible to study the transmission spectrum of the entire bank note instead of, or as a complement to, the reflection spectrum discussed above. Also, in order to obtain a superior discrimination, it is possible to use a wide spectral range for evaluation purposes, stretching from ultra-violet to infra-red (190 to about 3000 nm), which range can provide information of both colour pigment, and paper composition and structure.

For reasons of space-saving, it is possible to use light guides of fibreglass or plexiglass to transport light to and from the bank note and sensor/light source. In this way a much more compact embodiment can be achieved. The light guides also provide a simple way to obtain more information from the bank note in the form of certain additional integrals over the entire bank note such as fourier transforms or moments, preferably in conjunction with the spectral information described above.

CLAIMS

1. Apparatus for authenticating a bank note comprising:

an analyser operable to examine said note and to produce an output representative of properties thereof;

and a comparator operable to produce an output indicative of whether or not said note is authenticated based on a comparison of said analyser output with parameters representative of predetermined said properties:

characterised in that said analyser is operable to produce the same or substantially the same said output for different orientations and positioning of the same said bank note.

2. Apparatus according to claim 1, characterised in that the analyser is operable to examine all or substantially all of the surface of the bank note on at least one side thereof.

3. Apparatus according to claim 1 or 2, characterised in that the examined properties are integrated over the entire surface area subjected to said examination.

4. Apparatus according to any one of claims 1 to 3, characterised in that said analyser is a spectral analyser operable to analyse the spectral distribution of radiation reflected by or transmitted through the bank note from a multi-wavelength radiation source.

5. Apparatus according to claim 4, characterised in that said radiation source emits radiation with essentially continuous spectral distribution, and preferably comprises a filament lamp.

6. Apparatus according to any one of claims 1 to 3, characterised in that said analyser is a broad-spectrum radiation detector operable to receive the radiation reflected by or transmitted through the bank note from a set of substantially monochromatic radiation sources which are activated alternately one after the other in rapid succession.

7. Apparatus according to any one of claims 1 to 6, characterised in that said analyser is operable to analyse fourier components or moments of the intensity distribution of radiation reflected by or transmitted through the bank note.

8. Apparatus according to any one of claims 4 to 7, characterised in that said radiation is within the range extending from ultraviolet to infrared.

9. Apparatus according to claim 4 or 5, characterised in that said analyser incorporates an interference filter in which the essentially monochromatic band pass wavelength can be varied continuously.

10. Apparatus according to claim 4 or 5, characterised in that said analyser comprises a plurality of essentially monochromatic sensors, each one of which incorporates an interference filter with fixed, narrow band width and a band pass wavelength which is different for each sensor.

11. Apparatus according to claim 4 or 5, characterised in that said analyser comprises a plurality of sensors, each of which incorporates a light-emitting diode (Led) which is used as a detector with fixed, narrow band width and a band pass wavelength which is different for each detector.

12. Apparatus according to claim 6, characterised in that said broad-spectrum radiation detector comprises a photodiode or phototransistor, and said substantially monochromatic radiation source comprises light-emitting diodes of different spectral types, each of which emits radiation within a narrow spectral band which is different for each type.

13. Apparatus according to any one of claims 1 to 12, characterised in that even illumination and radiation reception is achieved by having the radiation source and the analyser at sufficient distance from the bank note.

14. Apparatus according to any one of claims 1 to 12, characterised in that even illumination and radiation reception is achieved in a compact manner by propagating the radiation through light guides.

15. Apparatus according to any one of claims 1 to 14, characterised in that said comparator comprises a microprocessor-based system which uses a comparison algorithm operable to identify the said bank note as a genuine bank note of a certain type if the absolute norm of the spectral shape of the bank note being examined with respect to a reference spectral shape for said type of bank note does not exceed a specified value, and to reject the bank note as false otherwise.

16. Apparatus according to claim 15, characterised in that said comparison algorithm incorporates a free normalization parameter allowing the comparison to be insensitive to, e.g. soiling of the bank note.

17. Apparatus substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

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